85-1020/

© Minister of Supply and Services Canada, 1984

Catalogue No: Fo46-16/64E

ISSN: 0704-772X

ISBN: 0-662-13242-2

Additional copies of this publication are available from:

Liaison and Information Services
Forest Pest Management Institute
Canadian Forestry Service
Department of the Environment
P.O. Box 490
Sault Ste. Marie, Ontario
Canada, P6A 5M7

Cette publication est aussi disponible en français sous le titre *Efficacité de la pulvérisation aérienne de Matacil® pour contrôler la tordeuse des bourgeons de l'épinette Choristoneura fumiferana (Clem.) à Bathurst, au Nouveau-Brunswick.*

# THE EFFICACY OF AERIALLY APPLIED MATACIL® TO CONTROL SPRUCE BUDWORM *CHORISTONEURA FUMIFERANA* (CLEM.) IN BATHURST, NEW BRUNSWICK

B.L. Cadogan, B.F. Zylstra, P. de Groot and C. Nystrom

Forest Pest Management Institute
Canadian Forestry Service
Environment Canada
P.O. Box 490
Sault Ste. Marie, Ontario
P6A 5M7

FPM-X-64

## ABSTRACT

Two Matacil® (Aminocarb) formulations were applied aerially, by a Cessna® 188B Ag-truck aircraft, as double applications. They were sprayed at 70 g A.I. in 1.5L total mix/ha to control spruce budworm, *Choristoneura fumiferana* (Clem.). Matacil 180F flowable insecticide was applied in both water and insecticide diluent ID585 while Matacil 1.8D oil soluble concentrate (OSC) was sprayed in ID585 and Sunspray® 6N oil. Atlox® 3409F, which was used as an emulsifier in the aqueous Matacil mixes, was also applied as a treatment at 0.04L in 1.5L total aqueous mix/ha to investigate its insecticidal activity.

Spray deposit recorded on ground level sample units showed that aqueous 180F deposited more sparsely (<2.0 drops/cm$^2$ and 0.07 L/ha) than either of the oil sprays. Volume Median Diameters (VMD) and Number Median Diameters (NMD) from both aqueous and oil mixes were <100 µm. Less than 0.35 drops/cm$^2$ and <0.003 L/ha of the Atlox sprays were recovered at ground level. Eighty-nine to ninety-four percent larval mortality were recorded in the aqueous Matacil 180F blocks and 72-83% in the areas sprayed with 180F in ID585. Defoliations in those treatment areas were 13.3-14.5 and 12.9-13.5% respectively. Larval reductions of 88% and 91% were recorded in the blocks treated with Matacil 1.8D in ID585 and Sunspray 6N respectively. The former experienced 8.7-19.9% defoliation and the latter 26%. There was 1.0% larval reduction and 56% defoliation in the Atlox treated block.

Matacil 180F sprayed in water or ID585 was as efficaceous in controlling spruce budworm, as Matacil OSC applied in ID585 or Sunspray 6N; and Atlox 3409F was not toxic to spruce budworm.



## RÉSUMÉ

Deux préparations de Matacil (aminocarbe) ont été pulvérisées du haut des airs par Cessna 188B Ag-truck, en double application à raison de 70 g d'ingrédient actif dans 1,5 L par hectare, contre la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana* [Clem.]). Le Matacil fluent 180F a été utilisé en mélange dans l'eau et due diluant 585(D585) tandis que le concentré oléosoluble Matacil 1.8D l'a été dans du D585 et de l'huile Sunspray 6N. L'émulsifiant Atlox 3409F des mélanges aqueux de Matacil, a également été pulvérisé à raison de 0,04 L dans un mélange aqueux de 1,5 L par hectare en vue d'en étudier l'action insecticide.

Les dépôts observés au sol ont montré que le Matacil 180F en préparation aqueuse s'est dispersé plus (<2,0 gouttes/cm$^2$ et 0,07 L/ha) que les pulvérisations huileuses. Le diamètre moyen en volume et le diamètre moyen en nombre des mélanges aqueux et huileux étaient inférieurs à 100 µm. Moins de 0,35 goutte/cm$^2$ et 0,003 L/ha des pulvérisations d'Atlox a été retrouvé au sol. On a enregistré des taux de mortalité de 89 à 94% chez les larves des blocs traités au Matacil 180F aqueux, et de 72 à 83% chez celles des blocs traités au Matacil 180F + D585. Les taux de défoliation dans les zones traitées étaient de 13,3 à 14,5% et de 12,9 à 13,5% respectivement. On a enregistré plus de 88% de réduction de larves dans les blocs traités au Matacil 1.8D + D585 et plus de 91%, dans les blocs traités au Matacil 1.8D + Sunspray 6N. Dans le premier cas, la défoliation était de 8,7 à 19,9% et dans le second, de 26%. Dans le bloc traité à l'Atlox, la diminution des larves était de 1% et la défoliation de 56%.

Le Matacil 180F pulvérisé dans l'eau ou le D585 a agi aussi efficacement contre la tordeuse que le concentré oléosoluble plus D585 ou Sunspray 6N; l'Atlox 3409F n'était pas toxique pour la tordeuse.

## ACKNOWLEDGMENTS

The authors would like to acknowledge with thanks, the assistance and cooperation of the following agencies and individuals: Gerry Davidson, Peter Ebling, Dave Ellis, Randall Prime and Dale Rogers, students at Sault College, Sir Sandford Fleming College, Queen's University, University of New Brunswick, and University of Waterloo respectively for their sustained efforts in the field; Mr. Les Wright, Chief Forester, N.B. Ministry of Natural Resources; Mr. Ed Kettela, MFRC and his assistants; Mr. H.J. (Bud) Irving and Forest Protection Ltd. who provided the aircraft services, and office and accounting facilities; Drs. C. Weisner and P. Silk, New Brunswick Research & Productivity Council,(RPC) for the analysis of the chemical residue on foliage; Dr. C.D. Dondale, Biosystematics, Canada Dept. of Agriculture who identified the spiders; Mr. Renaud Bourdache, the pilot; Dr. A. Drummond and the National Aeronautical Establishment who analyzed the Kromekote® cards; Mr. R.L. Misener and Chemagro Ltd., who kindly supplied the Matacil, and finally the St. Anne's Recreational Council, Bathurst, N.B. for use of their building as a laboratory.

TABLE OF CONTENTS


| | Page |
|---|---|
| ABSTRACT | (i) |
| RÉSUMÉ | (i) |
| ACKNOWLEDGMENTS | (ii) |
| LIST OF TABLES | (iii) |
| LIST OF FIGURES | (v) |
| INTRODUCTION | 1 |
| MATERIALS AND METHODS | 1 |
| *Site, Experimental Design and Block Establishment* | 1 |
| *Pesticide Formulations and Tank Mixes* | 5 |
| *Aircraft Parameters* | 6 |
| *Meteorological Monitoring* | 6 |
| *Communication* | 9 |
| *Spray Application* | 9 |
| *Spray Assessment* | 9 |
| Assessment on Artificial Media | 9 |
| Assessment of Foliage and Insects | 10 |
| Analysis of Foliage and Insects | 11 |
| *Biological Assessment* | 11 |
| Larval Sampling | 11 |
| Assessing Population Reduction | 11 |
| Arthropod Knockdown | 12 |
| Assessing Defoliation | 12 |
| RESULTS AND DISCUSSION | 12 |
| *Chemical Spray* | 12 |
| Mixing | 12 |
| Spray Deposit | 12 |
| Residue on Foliage & Insects | 15 |
| *Biological* | 15 |
| *Percent Population Mortality* | 26 |
| *Arthropod Knockdown* | 26 |
| *Defoliation* | 28 |
| *Spray Deposit-Spruce Budworm Relationships* | 28 |
| CONCLUSIONS | 29 |
| REFERENCES | 33 |

## LIST OF TABLES


| TABLE | | Page |
|---|---|---|
| I | Experimental site characteristics (Bathurst, N.B. 1981) . . . | 5 |
| II | Summary of spray formulations (Bathurst, N.B. 1981) . . . . . | 6 |
| IIIa | A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981) . . . . . | 7 |
| IIIb | A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981) . . . . . | 8 |
| IV | Bud development prior to the first spray. Bathurst, N.B. 1981 | 9 |
| V | Spruce budworm population (larval instar expressed as a percent) sampled prior to the 1st and 2nd sprays (Bathurst, N.B. 1981) . . . . . | 10 |
| VI | Summarized Matacil and Atlox ground level deposits (Bathurst, N.B. 1981) . . . . . | 16 |
| VII | Aminocarb residue on foliage, Bathurst, N.B. 1981 . . . . . | 17 |
| VIII | Larval spruce budworm population density on balsam fir *A. Balsamea* (Bathurst, N.B. 1981) . . . . . | 18 |
| IX | Larval spruce budworm population density on white spruce *P. glauca* (Bathurst, N.B. 1981) . . . . . | 19 |
| X | Larval spruce budworm population density on red spruce *P. rubens* (Bathurst, N.B. 1981) . . . . . | 20 |
| XI | Larval spruce budworm density on combined species *A. balsamea*, *P. glauca*, and *P. rubens* (Bathurst, N.B. 1981) . . . . . | 21 |
| XII | Larval spruce budworm population reduction and host tree defoliation on balsam fir *A. balsamea* (Bathurst, N.B. 1981) . | 22 |
| XIII | Larval spruce budworm population reduction and host tree defoliation on white spruce *P. glauca* (Bathurst, N.B. 1981) . . . . . | 23 |

LIST OF TABLES (concl'd)


| TABLE | | Page |
|---|---|---|
| XIV | Larval spruce budworm population reduction and host tree defoliation on red spruce *P. rubens* (Bathurst, N.B. 1981) . . | 24 |
| XV | Larval spruce budworm population reduction and host tree defoliation on combined species *A. balsamea, P. glauca,* and *P. rubens* (Bathurst, N.B. 1981) . . . . . | 25 |
| XVI | Spiders knocked down on three Matacil blocks (Bathurst, N.B. 1981) . . . . . | 29 |
| XVII | Droplet density and spruce budworm mortality on balsam fir *A. balsamea* (Bathurst, N.B. 1981) . . . . . | 30 |
| XVIII | Droplet density and spruce budworm mortality on white spruce *P. glauca* (Bathurst, N.B. 1981) . . . . . | 31 |
| XIX | Droplet density and spruce budworm mortality on red spruce *P. rubens* (Bathurst, N.B. 1981) . . . . . | 32 |

## LIST OF FIGURES


| FIGURE | | Page |
|---|---|---|
| 1 | The Aminocarb experimental research site near Bathurst, N.B. showing (1) to (9) the spray blocks and (c) the unsprayed check area (1981) . . . . . | 2 |
| 2 | Design of experimental block showing location of sample lines, marker balloons, hypothetical sample tree position and preferred wind direction . . . . . | 3 |
| 3 | Distribution of sample trees in spray blocks . . . . . | 4 |
| 4 | Diagram of the drop tray to collect dislodged spruce budworm . . . . . | 13 |
| 5 | Defoliation assessment method showing damage classes, class limits (as percent defoliation) and class means (in brackets). Modification of Fettes' Method (1950) . . . | 14 |
| 6 | Number of dead (A) and live (B) spruce budworm collected prior to and after Matacil sprays . . . . . | 27 |

## INTRODUCTION

Matacil® [Aminocarb); 4-(Dimethylamino)-3 methylphenol methyl-carbamate][1] has been used experimentally and operationally in forests in Canada and the United States since 1967. This insecticide was first used in forests as an emulsifiable concentrate (EC) (Randall 1967), and later as an oil soluble concentrate (OSC) with a phenolic emulsifier incorporated into the formulation. This latter formulation was credited with repeated successes in controlling larval populations of the eastern spruce budworm *Choristoneura fumiferana* (Clem.)[2], especially in eastern Canada. In 1978 concern was voiced about the aquatic toxicity of nonylphenol, the primary solvent cum emulsifier in the OSC formulation. This concern stimulated research into more acceptable formulations of Matacil.

In 1980 a new "flowable" or suspension concentrate (SC) formulation, Matacil 180F, was tested in the laboratory at the Forest Pest Management Institute (FPMI). This showed toxicity to budworm which was similar to the old formulations. (Pers. Comm. P.C. Nigam, B.V. Helson).

This research was conducted to determine (1) if the flowable Matacil sprayed aerially in both water and oil was as efficaceous as the old nonylphenol OSC formulation sprayed in oil, and (2) if and by how much does Atlox 3409F®[3], an exogenous emulsifier in the aqueous tank-formulations of the flowable, contribute to the insecticide's toxicity to budworm.

[1]Supplied by Chemagro Ltd. Mississauga, Ont., Canada.

[2]Lepidoptera: Tortricidae.

[3]Supplied by Atlas Chemicals Industries, Brantford, Ont.

## MATERIALS AND METHODS

*Site, Experimental Design and Block Establishment*

The trials were conducted in Gloucester County, approximately 25 km southwest of the city of Bathurst, New Brunswick, Canada. The experimental area was bounded by 65°30'W, 66°30'W longitude and 47°15'N, 47°35'N latitude (Fig. 1). The treatment blocks, measuring 0.5 x 1.0 km (50 ha), were situated in comparatively flat, mature forests comprised of various combinations of balsam fir, *Abies balsamea* (L.) Mill., spruce *Picea* spp. and hardwoods. Each block was aligned in relation to a road and the boundaries were defined with balloons as illustrated in Figure 2. Two transects were cleared across each block. These lines were divided into 33 equal segments and 25-30 sample trees were selected within easy reach of the line (Fig. 3). The sample trees were marked with a fluorescent orange cloth cross-punched into the tree cambium. Trees, particularly those which neighbored the sample trees, were judiciously removed to create discrete canopy openings and ground clearings approximately 7-8 m in diameter. The openings facilitated relatively unrestricted movement of spray droplets in the vicinity of the sample tree, thus improving droplet deposition onto the tree itself as well as at the forest floor level.

An area which was not surveyed in the regular rectangular configuration was established as an untreated check block and was left undisturbed so that the larval population dynamics of *C. fumiferana*, affected by factors other than insecticidal treatments, could be measured and recorded.

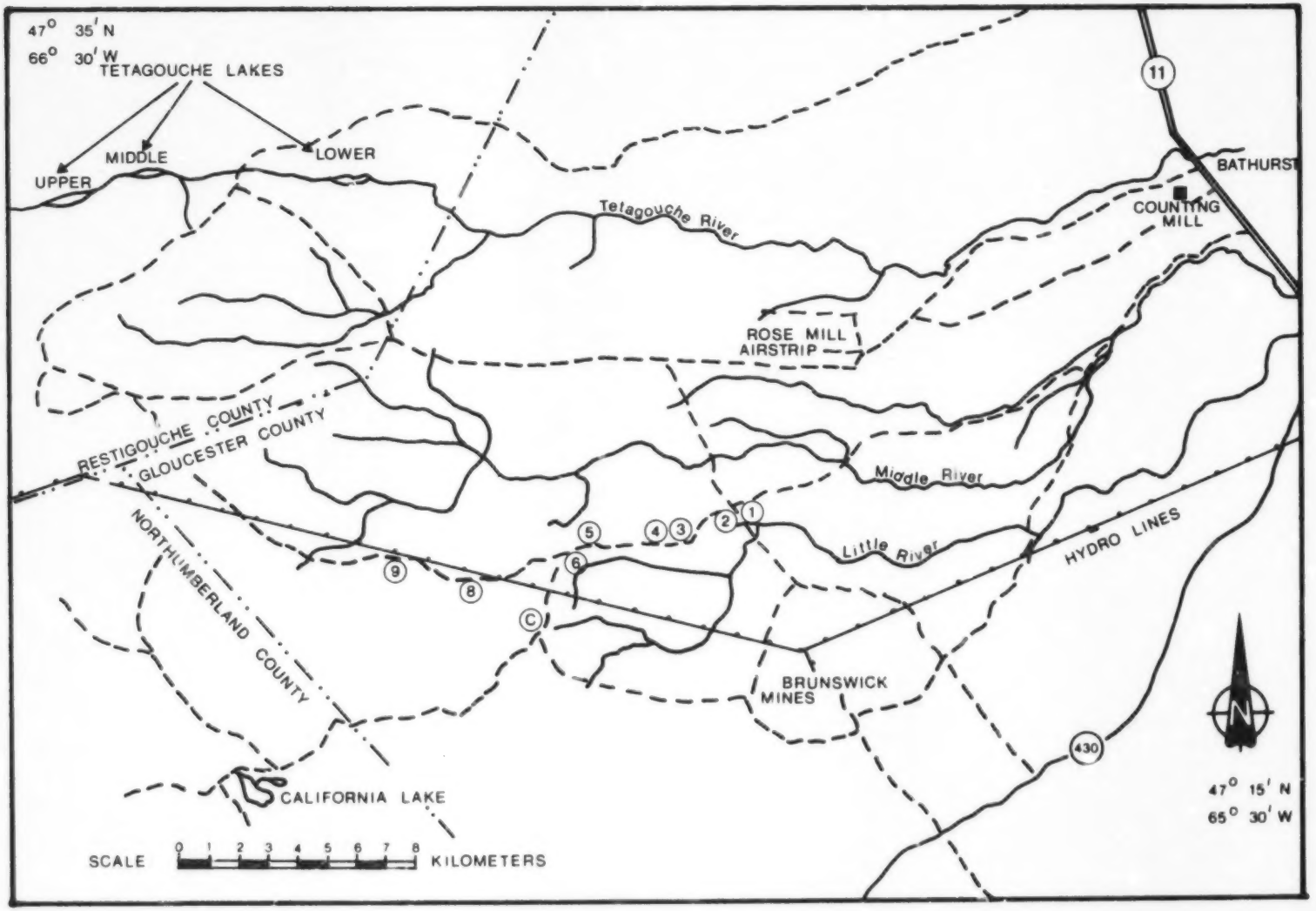


Fig. 1. The aminocarb experimental research site near Bathurst, N.B. showing ( 1-9 ) the spray blocks and C , the unsprayed check area. (1981)

Environment Canada
Canadian Forestry Service

Environnement Canada
Service canadien des forêts

# The Efficacy of Aerially Applied Matacil to Control Spruce Budworm Choristoneura fumiferana (Clem.) in Bathurst, New Brunswick

B.L. Cadogan, B.F. Zylstra, P. deGroot and C. Nystrom

Information Report FPM-X-64
Forest Pest Management Institute

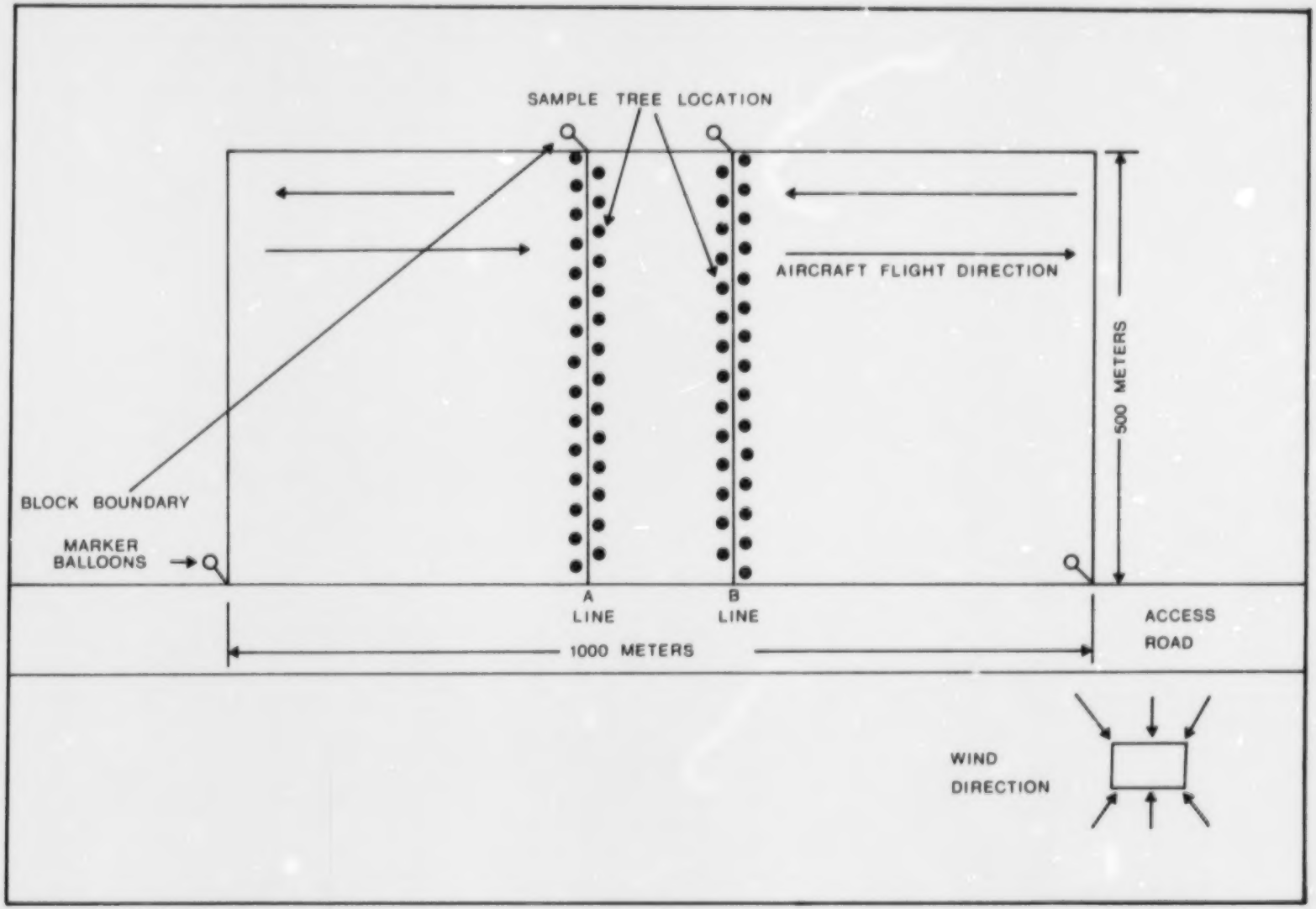


Fig. 2. Design of experimental block, showing location of sample lines, marker balloons, hypothetical sample tree position and preferred wind direction.

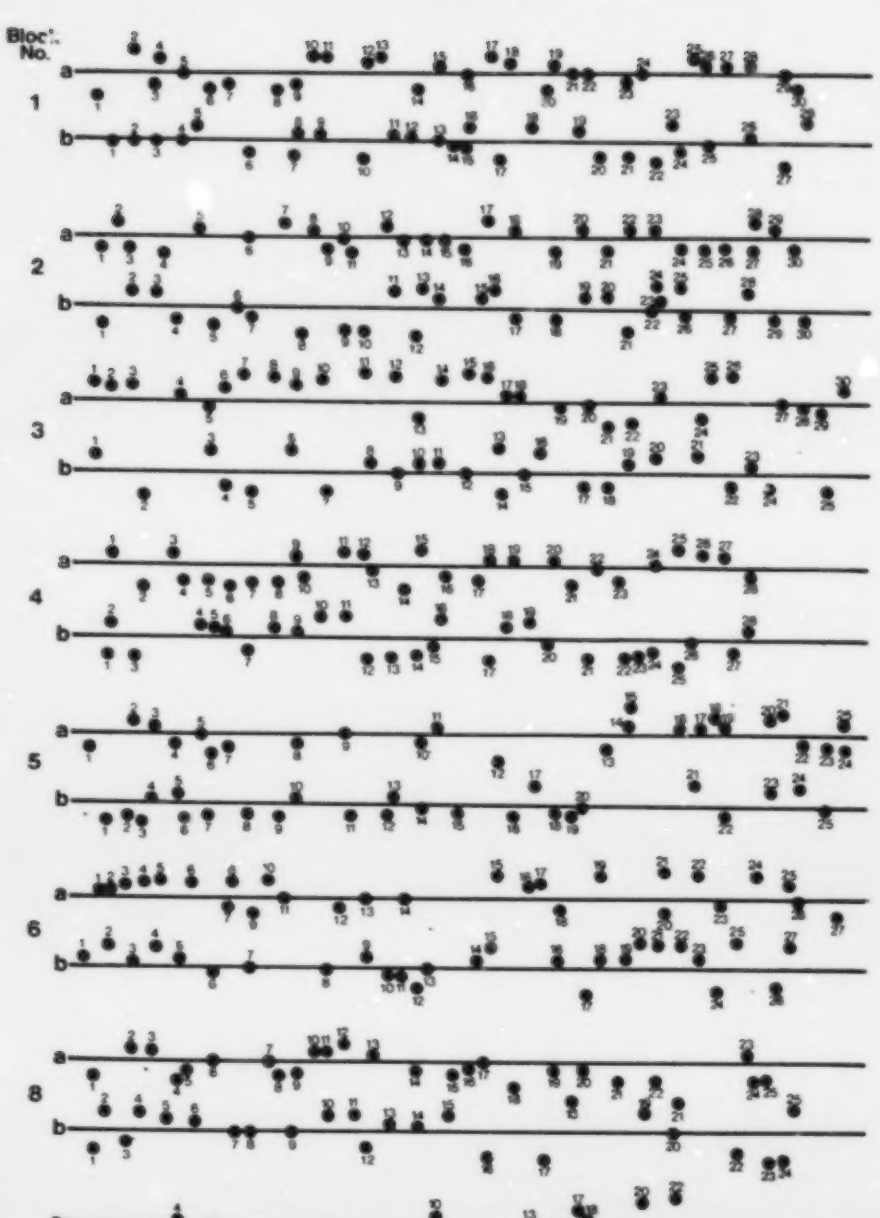


Fig. 3. Distribution of sample trees in spray blocks.

Forest stand characteristics of the blocks are presented in Table I.

*Pesticide Formulations and Tank Mixes*

Two different formulations of Matacil and one of Atlox 3409F were applied as treatments.

Matacil® 180F, flowable insecticide consists of very fine Aminocarb Technical particles suspended with special additives in an oil and contains 180 g (AI) litre$^{-1}$. Matacil® 1.8D is an oil soluble concentrate (OSC), which contains 1.8 lbs AI U.S. gallon$^{-1}$ and nonylphenol as a primary solvent. These metric and imperial AIs are equivalent.

Table I. Experimental site characteristics (Bathurst, N.B. 1981)

| | | Species Composition | | | Number of Trees per Transect | | | Sample Tree Characteristics: Tree Height | | Sample Tree Characteristics: Diameter at 1.3 Metres | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Block | Treatment* | Conifer % | Hardwood % | Transect | Balsam fir | White spruce | Red spruce | m $\bar{X}$ | m ± S.D. | cm $\bar{X}$ | cm ± S.D. |
| 1 | 180F + $H_2O$ + Atlox | 70 | 30 | A | 23 | 5 | 2 | 15.20 | 1.82 | 25.90 | 5.86 |
| | | | | B | 20 | 0 | 8 | 14.36 | 2.84 | 24.68 | 5.05 |
| 2 | 180F + $H_2O$ + Atlox | 85 | 15 | A | 28 | 0 | 2 | 13.39 | 1.80 | 22.97 | 4.53 |
| | | | | B | 29 | 0 | 1 | 13.69 | 2.06 | 23.93 | 4.66 |
| 3 | 180F + ID585 | 50 | 50 | A | 16 | 14 | 0 | 15.03 | 2.12 | 26.06 | 6.66 |
| | | | | B | 23 | 0 | 2 | 13.28 | 2.63 | 21.33 | 5.52 |
| 4 | 180F + ID585 | 65 | 35 | A | 16 | 5 | 7 | 14.46 | 2.13 | 26.54 | 6.18 |
| | | | | B | 18 | 7 | 3 | 13.82 | 1.16 | 23.60 | 3.56 |
| 5 | 1.8D + GN | 60 | 40 | A | 16 | 4 | 5 | 13.17 | 1.39 | 21.62 | 5.71 |
| | | | | B | 17 | 8 | 0 | 13.16 | 1.64 | 21.72 | 6.27 |
| 6 | 1.8D + GN | 80 | 20 | A | 21 | 1 | 5 | 13.73 | 2.23 | 22.07 | 4.72 |
| | | | | B | 19 | 2 | 6 | 13.21 | 2.56 | 21.66 | 4.44 |
| 8 | 1.8D + ID585 | 50 | 50 | A | 17 | 5 | 3 | 13.83 | 1.74 | 22.67 | 5.08 |
| | | | | B | 17 | 5 | 3 | 13.52 | 1.12 | 22.89 | 6.18 |
| 9 | Atlox + $H_2O$ | 50 | 50 | A | 15 | 4 | 6 | 13.22 | 1.88 | 24.59 | 6.70 |
| | | | | B | 15 | 6 | 4 | 13.89 | 1.58 | 23.36 | 6.35 |
| Check | Untreated | 90 | 10 | - | 30 | 15 | 15 | 13.06 | 1.60 | 22.27 | 3.71 |

*Matacil for blocks 1 to 8.

Atlox 3409F is a polyoxylene derivative and is used widely as an emulsifying agent in paints throughout North America.

Matacil 180F was mixed for application both in water and in insecticide diluent (I.D.) 585 in proportions as listed in Table II. Atlox was added as an emulsifier only to the aqueous solutions. Because Matacil tends to be unstable in highly alkaline media, care was taken to ensure that the solvent's pH was between 6.5-7.0. Matacil 1.8D was mixed in Sunspray® 6-N oil[4] and in I.D. 585 while Atlox as a treatment was mixed in water alone.

These mixes were dyed; the oil solutions with Automate® "B" red dye[5] and the aqueous ones with Rhodamine® "B" red dye[6] in order to facilitate spray deposit assessment.

In the insecticidal sprays all Matacil treatments were applied at 70.0 g (AI)/ha and Atlox at 0.04 L/ha. Application volumes for all treatments were 1.5 L/ha. A summary of these tank mix data is shown in Table II.

Table II. Summary of spray formulations (Bathurst, N.B. 1981)

| Block No.s | Insecticide Formulation | * | Volume L/ha | Volume % |
|---|---|---|---|---|
| 1 & 2 | Matacil 180F | a | 0.389 | 25.9 |
| | Atlox 3409F | b | 0.020 | 1.3 |
| | Water | c | 1.083 | 72.3 |
| | Rhodamine B Red Dye | d | 0.008 | 0.5 |
| 3 & 4 | Matacil 180F | b | 0.389 | 25.9 |
| | Shell ID585 | a | 1.081 | 72.1 |
| | Automate B Red Dye | c | 0.030 | 2.0 |
| 5 & 6 | Matacil 180F | b | 0.389 | 25.9 |
| | Sunspray 6N | a | 1.081 | 72.1 |
| | Automate B Red Dye | c | 0.030 | 2.0 |
| 8 | Matacil 1.8D | b | 0.389 | 25.9 |
| | Shell ID585 | a | 1.081 | 72.1 |
| | Automate B Red Dye | c | 0.030 | 2.0 |
| 9 | Atlox 3409F | a | 0.044 | 2.9 |
| | Water | b | 1.448 | 96.6 |
| | Rhodamine B Red Dye | c | 0.008 | 0.5 |

*Ingredients mixed in alphabetical order.

*Aircraft Parameters*

The treatments were applied by a Cessna 188 Ag-truck fitted with four AU 3000 Micronair atomizers.[7] The rate of flow was controlled to emit a total of 23.5 L/min and a calculated swath width of approximately 60 meters. The aircraft flew at 160 km/hr and about 15-17 m above the tree canopy. Airport facilities were provided at South Tetagouche (Fig. 1), which is approximately 6 minutes ferrying time from the experimental site. The flight lines of the aircraft during spray were generally perpendicular to the prevailing wind (Fig. 2). Data relevant to the aircraft are presented in Tables IIIa and IIIb.

*Meteorological Monitoring*

Weather is a very influential variable in determining the effectiveness of a compound in the field. Because the researcher has no direct control over these elements, weather conditions during the trials were monitored and the data used to determine suitable spray conditions and in explaining aspects of the results.

[4]Supplied by Sunoco Inc., Toronto.
[5]Supplied by Morton William Chemical Ajax, Ontario.
[6]Supplied by C.I.L. Willowdale, Ont.
[7]Supplied by Micronair (Aerial Ltd., Sandown, Isle of Wight, England.

Table IIIa. A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981)

| | Block 1 and 2 | | Block 3 and 4 | | Block 5 and 6 | |
|---|---|---|---|---|---|---|
| | 1st applic. | 2nd applic. | 1st applic. | 2nd applic. | 1st applic. | 2nd applic. |
| **Date** | 12-06-81 | 18-06-81 | 12-06-81 | 18-06-81 | 13-06-81 | 18-06-81 |
| Time (hrs) | 1940 | 0620 | 2100 | 0715 | 2010 | 2015 |
| Insecticide | Matacil 180F | | Matacil 180F | | Matacil 1.8 OSC | |
| Active ingredient (g/ha) | 70 | | 70 | | 70 | |
| Solvent | $H_2O$ | | *Shell I.D. 585 oil | | Sunspray 6N oil | |
| Block size (ha) | 50 | | 50 | | 50 | |
| **Aircraft** | | | | | | |
| Type | Cessna 188 Ag Truck | | Cessna 188 Ag Truck | | Cessna 188 Ag Truck | |
| Speed km/h | 160 | | 160 | | 160 | |
| Applic. height (m) | 29-31 | 27 | 24 | 27-30 | 27-30 | 27-30 |
| Applic. equipment | (4) Micronair AU 3000 | | (4) Micronair AU 3000 | | (4) Micronair Au 3000 | |
| Emission rate (L/min) | 23.5 | | 23.5 | | 23.5 | |
| Applic. rate (L/ha) | 1.5 | | 1.5 | | 1.5 | |
| Blade angle | 25° | | 25° | | 25° | |
| Blade rpm | Maximum | | Maximum | | Maximum | |

| | Block 1 | | Block 2 | | Block 3 | | Block 4 | | Block 5 | | Block 6 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Weather** | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Temp. °C (mean) | 13.00 | 10.25 | 13.00 | 10.75 | 10.00 | 13.75 | 10.00 | 13.75 | 16.50 | 22.25 | 17.25 | 20.75 |
| RH % (mean) | 80 | 100 | 83 | 96 | 96 | 73 | 96 | 73 | 73 | 58 | 69 | 56 |
| Wind speed ($\bar{X}$ km/h) | 0.5 | 1.0 | 0.5 | 2.0 | 0.5 | 5.0 | 0.5 | 5.0 | 0.5 | 1.5 | 0.5 | 1.0 |
| Wind direction | E | W | E | SW-W | E | W | E | W | SE-SW | W | SE-S | W |
| Stability** | ↓ | ↓ | ↓ | ↓ | ←→ | ↓ | ←→ | ↓ | ↓ | ↓ | ↓ | ↓ |
| Cloud cover | 1/10 | 0/10 | 1/10 | 1/10 | 0/10 | 0/10 | 0/10 | 1/10 | 0/10 | 0/10 | 0/10 | 0/10 |

*I.D.--Insecticide diluent.

**↓--Inversion.
↑--Lapse.
←→--Neutral (isothermic).

Table IIIb. A summary of spray, aircraft and weather data for Matacil efficacy trials (Bathurst, N.B. 1981)

| | Block 8 | | Block 9 | |
|---|---|---|---|---|
| | 1st applic. | 2nd applic. | 1st applic. | 2nd applic. |
| **Date** | 16-06-81 | 19-06-81 | 15-06-81 | 19-06-81 |
| Time (hrs) | 0600 | 0715 | 2020 | 0600 |
| Insecticide | Matacil 1.8 OSC | | Atlox 3409F | |
| Volume Active Ingredient (g/ha) | 70 | | | |
| Solvent | Shell I.D. 585* | | $H_2O$ | |
| Plot size (ha) | 50 | | 50 | |
| **Aircraft** | | | | |
| Type | Cessna 188 Ag-Truck | | Cessna 188 Ag-Truck | |
| Speed (Km/h) | 160 | | 160 | |
| Applic. height (m) | 27 | 24-27 | 27-30 | 24 |
| Applic. equipment | (4) Micronair AU 3000 | | (4) Micronair AU 3000 | |
| Emission rate (L/min.) | 23.5-24.2 | 23.5 | 23.5 | 23.5 |
| Applic. rate (L/ha) | 1.5 | | 1.5 | |
| Blade angle | 25° | | 25° | |
| Blade rpm | Maximum | | Maximum | |
| **Weather** | | | | |
| Temp. °C (mean) | 10.0 | 18.0 | 12.5 | 13.75 |
| RH% (mean) | 80 | 87 | 77 | 85 |
| Wind speed (X Km/h) | 0.50 | 1.0 | 0.50 | < 0.5 |
| Wind direction | S-SW | W-NW | SE-S | SW |
| Stability** | ↑ | ↓ | ↑ | ↓ |
| Cloud cover | 10/10 | 0/10 | 10/10 | 0/10 |

*I.D.--Insecticide diluent.

** ↓--Inversion.
↑--lapse.
↔--Neutral (isothermic).

The meteorological data were collected by an assembly of nonrecording instruments. A Heathkit weather computer model I.D. 4001 was the central instrument displaying digital readouts, which were manually recorded at 5-minute intervals. An anemometer/vane to measure wind velocity and direction was attached to the top of a 12.8 m mast, and temperature probes were fitted at the 12.6 m and 2.0 m levels to determine the atmospheric stability. Wet and dry bulb temperature readings, from which relative humidities

were calculated were obtained from a motor psychrometer. These instruments and equipment were fitted onto a vehicle, and maneuvered to locations nearest the test block where meteorological conditions could be considered representative of those in the block. Weather conditions were monitored from 1.5 h prior to each spray until 1 h after. Tables IIIa and IIIb summarize the data obtained from the weather monitoring.

*Communication*

A radio network was established and contact was maintained between the airport and the base station, and the aircraft and mobile ground stations in the experimental blocks. Red colored helium filled balloons acted as the ground markers to define the block boundaries for the pilot (Fig. 2).

*Spray Application*

There is an intimate synchrony between the phenological development of the host tree and the development of budworm (Blais 1957). Each host species develops at a different rate and so do the budworm on it. Feeding responses and mobility of budworm and eventually accessibility with insecticides are related to the phenological development of buds, thus the timing of the initial sprays is critical if the most effective response is to be achieved.

The timing of the first spray during this study was based on a quantitative assessment of the bud development of the major tree species within 4 blocks. On the first application date (81-06-12) the buds on white spruce, *Picea glauca* (Moench) Voss, and balsam fir were fully flared and shoot growth from pooled samples measured $\bar{X}$ = 2.8 cm (n = 379) and $\bar{X}$ = 2.2 cm (n = 382) respectively. The second spray was applied (Table III) primarily to replenish the aminocarb of the first, which after approximately 3-4 days began to dissipate. Table IV shows the shoot development in the 4 individual blocks; approximately 90% of the buds on red spruce were still tightly closed. Larval development at that time is shown in Table V.

Table IV. Bud development prior to the first spray. Bathurst, N.B. 1981

| Treatment block | Tree Species* | Mean Shoot Length ± S.D. (cm) |
|---|---|---|
| 1 | Sw | 2.70 ± 0.75 |
| | Bf | 1.66 ± 0.40 |
| 2 | Sw | 3.60 ± 1.30 |
| | Sr | 0.76 ± 0.25 |
| | Bf | 2.30 ± 0.57 |
| 3 | Sw | 2.60 ± 0.77 |
| | Sr | 0.63 ± 0.19 |
| | Bf | 1.70 ± 0.35 |
| 4 | Sw | 2.46 ± 0.84 |
| | Sr | 0.94 ± 1.25 |
| | Bf | 3.00 ± 0.80 |

*Sw: White spruce; Sr: red spruce; Bf: balsam fir.

*Spray Assessment*

Assessment on Artifical Media.

To assess the spray efficiency of the various formulations and tank mixes a sampling unit comprised of a Kromekote® card (10 x 10 cm) and two glass slides (5.0 x 7.5 cm), as described by Randall (1980), was placed in the clearing adjacent to each sample tree. These units were placed approximately 30 min before the spray and retrieved approximately 50 min after its completion. The cards and slides were stored in dry, dark conditions prior to evaluation. The cards were sent to the

Table V. Spruce budworm populations (larval instar expressed as a percent) sampled prior to the 1st and 2nd sprays. (Bathurst, N.B. 1981)

| Block | Sampling Date | Instar | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | 2nd | 3rd | 4th | 5th | 6th | Pre-pupa | Pupa |
| Bk 1 | June 12 | 2.3 | 30.6 | 36.7 | 23.5 | 6.9 | 0.0 | 0.0 |
| | June 18 | 0.0 | 14.8 | 30.1 | 17.5 | 36.6 | 0.7 | 0.2 |
| Bk 2 | June 12 | 8.5 | 35.5 | 33.6 | 15.6 | 6.7 | 0.0 | 0.0 |
| | June 18 | 0.8 | 20.5 | 31.4 | 19.2 | 28.1 | 0.0 | 0.0 |
| Bk 3 | June 12 | 7.5 | 30.7 | 28.1 | 14.4 | 19.4 | 0.0 | 0.0 |
| | June 18 | 0.0 | 16.1 | 20.8 | 19.4 | 41.4 | 0.7 | 1.5 |
| Bk 4 | June 12 | 1.9 | 22.3 | 25.2 | 23.7 | 26.5 | 0.4 | 0.0 |
| | June 18 | 0.0 | 11.5 | 17.3 | 26.5 | 42.8 | 0.8 | 1.0 |
| Bk 5 | June 13 | 4.7 | 32.5 | 33.6 | 13.7 | 15.6 | 0.0 | 0.0 |
| | June 18 | 0.0 | 5.3 | 26.6 | 29.9 | 38.2 | 0.0 | 0.0 |
| Bk 6 | June 13 | 3.1 | 29.7 | 34.5 | 18.2 | 14.5 | 0.0 | 0.0 |
| | June 18 | 0.0 | 10.2 | 24.9 | 34.4 | 30.5 | 0.0 | 0.0 |
| Bk 8 | June 16 | 1.1 | 16.4 | 24.9 | 21.2 | 36.4 | 0.0 | 0.0 |
| | June 19 | 0.0 | 4.0 | 18.1 | 23.0 | 54.5 | 0.1 | 0.3 |
| Bk 9 | June 16 | 0.5 | 9.2 | 22.2 | 23.4 | 44.7 | 0.0 | 0.0 |
| | June 19 | 0.0 | 2.2 | 12.6 | 22.0 | 62.4 | 0.3 | 0.5 |

National Aeronautical Establisiment, Ottawa, Canada where they were analyzed by a Flying Spot Scanner (Drummond 1980) and the droplet density and other characteristics of the spray spectra were determined.

In the laboratory at FPMI each glass slide was washed with an appropriate solvent; i.e., Toluene with the oil mixes and absolute alcohol with the aqueous ones. Colorimetric analysis of the dye content was performed using a Bausch and Lomb spectronic 100 Spectrophotometer.

Thus a quantitative (number of drops and volume of insecticide) as well as a qualitative (types of drops) assessment of the spray recovered at ground level were obtained.

Assessment of Foliage and Insects.

Host tree foliage and insects were investigated for residual aminocarb, which also gave a quantitative assessment of the spray which was deposited in the budworm's

feeding habitat. After the sampling units were retrieved from the blocks sprayed with the two Matacil formulations, in three different carriers, foliage was taken randomly from the midcrown of 10 trees in each treatment. Approximately 20 g of new growth was snipped with scissors and, without being handled, allowed to fall into amber colored bottles. The bottles were wrapped in aluminum foil and placed in a Thermos® picnic cooler half filled with ice. Approximately 10 g of budworm were removed from sample branches with #0 camel hair brushes and placed into identical bottles. The bottles were wrapped in aluminum foil and stored as described above. These foliage and insect samples were dispatched to New Brunswick Research and Productivity Council (RPC), Fredericton where they were analyzed.

Analysis of Foliage and Insects.

Analysis was carried out at RPC following the procedure of K.M.S. Sundaram *et al.* (1976) except that no derivitization of the Aminocarb was undertaken. Aminocarb was analyzed on a Hewlett-Packard Model 5830A gas chromatograph fitted with a flame-ionization detector. The column used was a glass 2 m x 2 mm 3% SE 30 on Gas Chrom Q (800/100 mesh). Recoveries from foliage extracts fortified with Matacil at levels of 5.0, 2.5, 1.0, 0.25 and 0.125 µg/g levels averaged 100%. The minimum level of detection was 0.2 µg/g for a 10-g sample (P.J. Silk *et al.* pers. comm.).

*Biological Assessment*

Larval Sampling.

Samples consisting of two 46-cm branches, one each from the upper and midcrown areas, were taken from each sample tree. The branches were cut with pole pruners with attached baskets and lowered to the forest floor. Each branch was placed in a large (16.0-kg capacity) paper bag and stapled shut to prevent larval escape. The samples were taken to a counting mill at the field laboratory in Bathurst. The number of viable buds was counted and the living spruce budworm larvae were removed by beating the flushed shoot as described by Martineau and Benoit (1973) or by dissecting the buds which were still closed. In the prespray counts the needles were also closely examined under 100W lamps to account for early instars which might have still been in mines.

Assessing Population Reduction.

Assessing the levels of spruce budworm population decline assists in determining the effects of the treatments. The populations in the blocks were assessed at each sampling date by calculating the number of larvae per bud and the number per 46-cm branch for each sample tree. These two methods were used primarily to determine which might be more suitable for future research use. The percent population reductions recorded in the treatment blocks were corrected for natural mortality using Abbott's formula (Abbott 1925):

$$100\ (C-T)/C = \%\ \text{corected control}$$

where C = % living in the untreated block

T = % living in the treated block

During this study, as often happens in large-scale forest trials, unfavorable weather and logistical support prevented the simultaneous or synchronous sampling of treated and untreated blocks. Uniformity of experimental conditions is a presumed and accepted prerequisite when applying the correction formula, so it was necessary to accurately determine the larval densities in both the treated and untreated blocks on any particular sampling date. This was accomplished by using the seasonal population data and generating best-fit exponential decay curves for each block. From these curves it was then possible to extract population densities and compute C and T on given dates.

Arthropod Knockdown.

Trays, built as shown in Figure 4, were placed on the forest floor just on the drip circle of 10 trees in blocks #2,#4, #6 and the untreated check. The sheer acted like a net and immobilized the larvae and other small arthropods. Trays were placed prior to the sprays and monitored after them to investigate if the 'flowable' exhibited unusual knockdown of arthropods.

Assessing Defoliation.

After the budworm had pupated and the moths emerged two branch samples were taken from each sample tree as described above. These branches were evaluated, to determine to what extent defoliation had occurred, using Kettela's method (E. Kettela, pers. comm. 1981) which involved a component of Fettes' (1950) method. The shoots from the 46-cm branch were removed and pooled. From this pool, 100 shoots were assessed randomly. In cases where there were < 100 shoots on a branch the entire pool was used. The damage on each shoot was assessed according to Fettes (1950). Six damage classes (Fig. 5) were used instead of 12 as recommended by Fettes (1950), as the authors agreed with Kettela (Pers. Comm.) that 12 classes introduced much more subjectivity than 6.

## RESULTS AND DISCUSSION

*Chemical Spray*

Mixing.

The Matacil flowable formulation mixed with both ID585 and water without any problem. The workers experienced no unusual discomfort at the mixing site.

Spray Deposit.

As a carrier of insecticides in Canada, water has the advantages of being easily available and inexpensive, but has the disadvantage of having a high propensity to evaporate in conditions of low relative humidity. This significantly affects the deposition of droplets. Droplet density and size spectra are important factors which influence the efficacy of aerially applied pesticides by determining adequate or inadequate coverage of the target.

In this study the droplet spectra and volume deposits resulting from both applications, measured on Kromekote cards at ground level, are shown in Table VI. These might be conservative assessments as the Flying Spot Scanner's analytical method could not detect droplet stains <30 µm in diameter. The Matacil 180F aqueous mixes (Blocks 1 and 2) deposited <2.0 drops/cm$^2$ consistently for both applications whereas the oil mixes of both the Matacil flowable and 1.8D showed significantly ($P = 0.05$) different mean droplet densities between the first and second applications. Aqueous 340F deposited <0.5 drops/cm$^2$ for both applications which represents the least deposit of all the treatments.

Deposits expressed as droplet density or as volume (L/ha) recovered, (as eluted from glass slides) are usually heterogeneous. The results from these trials show there was a significant difference in droplet density between the block transects for the first application only in blocks 6, 8 and 9. For the second application, significant differences between transects were observed in blocks 5 and 8. Differences in eluted volumes were recorded for the first application in blocks 3 and 8 and for the second application, in block 8 only. Some of these differences might have been due to the tank formulation but a forest is a very dynamic system and many other variables might also be responsible for them. Inter block differences are noted in Table VI.

Droplet size is usually expressed as volume median diameter (VMD), the droplet diameter

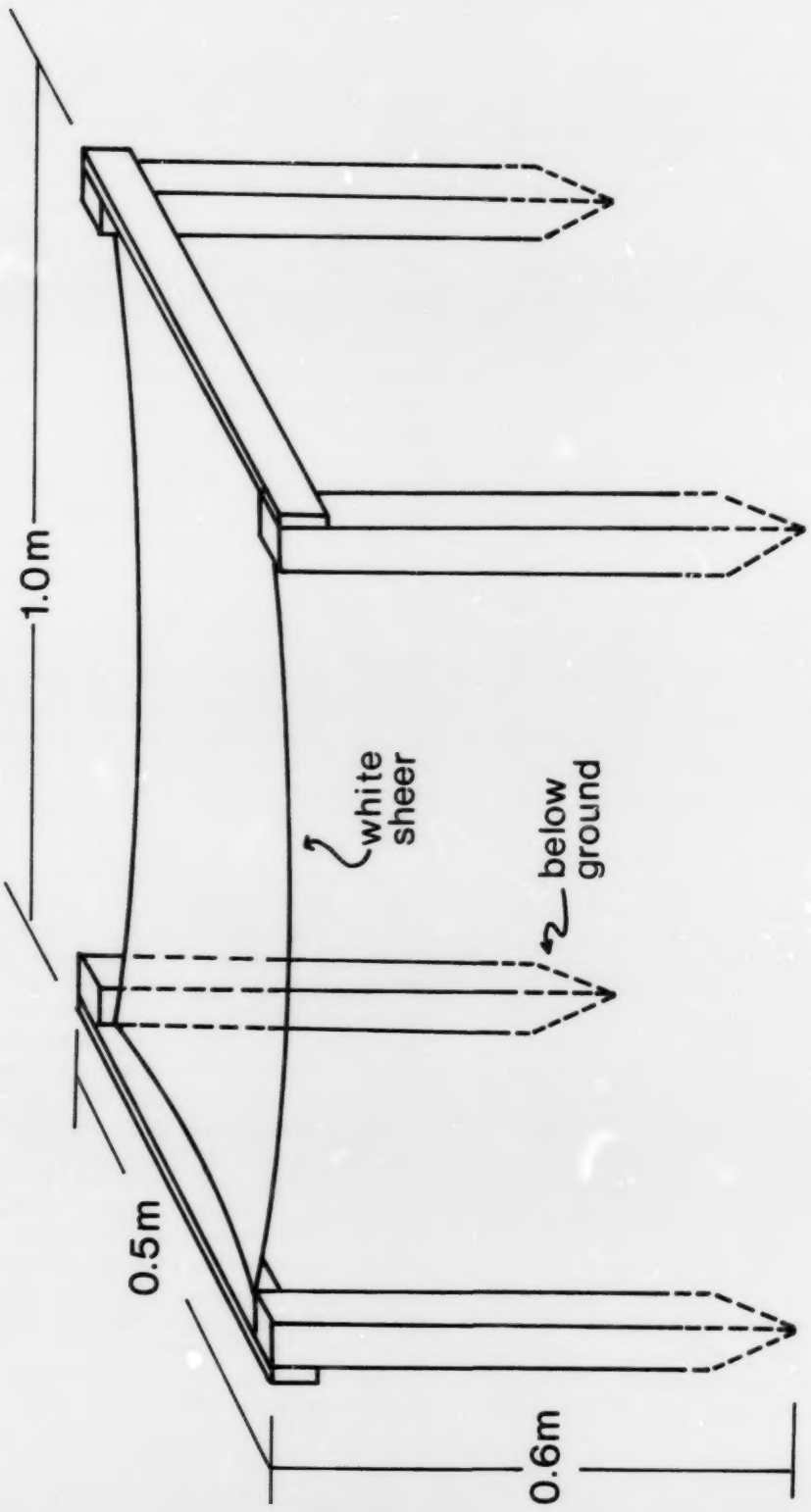


Fig. 4. Diagram of the drop tray to collect dislodged spruce budworm.

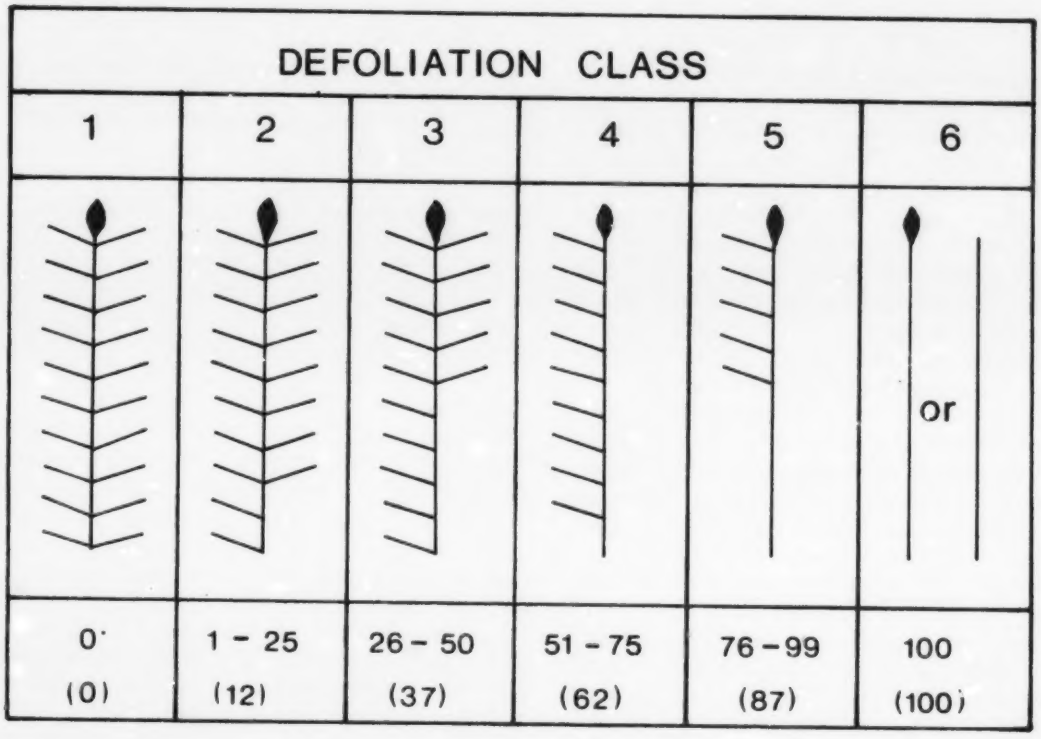


Fig. 5. Defoliation assessment method showing damage classes, class limits (as percent defoliation,) and class mean (in brackets.) -Modification of Fettes' Method (1950)

that divides the spray volume into two equal parts, i.e., 50% of the volume in droplets <VMD and 50% above it. A desirable insecticidal VMD for defoliating forest insects is considered generally to be <100 µm (Himel & Moore 1967; Barry *et al.* 1977; Joyce & Spillman 1978). All the treatments of the first application produced VMDs in the 60-80 µm range. In the second application, while VMDs for the Matacil 180F in ID585 treatments remained in this range, those for 180F in water increased to approximately 100 µm. Matacil 1.8D in 6N oil produced a dense profile, consequently the Flying Spot Scanner had difficulty in analyzing what it considered "good droplets" on the cards. Thus no definitive size measurements of the droplets from these treatments were available. It was evident that the RH recorded at the times of the sprays (Tables IIIa and IIIb) influenced the evaporation and consequently the VMD, especially of the aqueous Matacil treatments (Table VI). Where the RH changed considerably the droplets of aqueous mixes responded accordingly; oil, however, did not appear to respond as sensitively even to significant changes in RH. The Atlox spray did not appear to react to small RH changes.

Although evaporation of aqueous droplets seems to be a liability, it might feasibly be manipulated to provide a desirable VMD. It is possible that by knowing or being able to predict the degree of evaporation which will occur it will be feasible to create the initial droplet size at the correct altitude which will ultimately deposit with optimum diameters.

Residue on Foliage & Insects.

The Aminocarb residues recovered from foliage in 4 treatment blocks are shown in Table VII. These values were calculated from deposits which ranged from nondetectable to 3.6 µg/g foliage. Only balsam fir foliage had recoverable levels of deposit from both oil and aqueous treatments of Matacil. None of the samples of budworm, comprising mainly dead and moribund larvae removed from sprayed foliage, had detectable levels of Matacil. This might possibly be because the AI which affected or killed larvae, irregardless of its mode of entry, was on a µg/g basis below detectable levels or the insects metabolized the AI (no tests were conducted for derivatives).

*Biological*

The effectiveness of insecticides sprayed against spruce budworm is usually assessed primarily by the postspray responses of the insect. These responses are normally measured by the degree of population decline and/or the extent of host tree defoliation. In these trials assessments were based on the insect responses on the three host species individually and as a combined unit. The phenological development of the three species differed substantially in the research area. Balsam fir and white spruce developed similarly and ∿10 days earlier at the onset than red spruce. Since larval development is closely synchronized with host tree development (Blais 1957), the timing of pesticide applications tends to affect budworm populations differently in a multispecies complex than in a forest with a single species as its major component.

During this study the first spray applications coincided with substantial shoot development of the two major host species, balsam fir and white spruce (Table IV) and of the budworm larvae (Table V), thus potentially making the larvae more vulnerable to the spray deposit.

Spruce budworm densities influenced by the insecticide treatments are summarized in Tables VIII-XI. Tables XII and XV show how these influences are reflected when measured by percent mortality. Responses on balsam fir, white and red spruce are recorded in Tables VIII and XII, IX and XIII, and X and XIV respectively, while those based on the combined species are shown in Tables XI and

Table VI. Summarized Matacil and Atlox ground level deposits (Bathurst, N.B. 1981)

| Block No. | Treatment | 1st Appl. Drops/cm² $\bar{X}$ ± S.D. | 1st Appl. Volumes L/ha $\bar{X}$ ± S.D. | 1st Appl. NMD (µm) | 1st Appl. VMD (µm) | 1st Appl. $D^{max}$ (µm) | 2nd Appl. Drops/cm² X ± S.D. | 2nd Appl. Volumes L/ha X ± S.D. | 2nd Appl. NMD (µm) | 2nd Appl. VMD (µm) | 2nd Appl. $D^{max}$ (µm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 180F + water | 1.76 ± 1.97[a] | 0.016 ± 0.020[a] | 50.4 | 61.1 | 142.2 | 1.20 ± 0.86[a] | 0.059 ± 0.043[a] | 95.1 | 99.2 | 168.9 |
| 2 | 180F + water | 1.73 ± 1.93[a] | 0.017 ± 0.023[a] | 51.9 | 62.7 | 125.9 | 1.22 ± 1.34[a] | 0.062 ± 0.082[a] | 97.0 | 100.1 | 163.6 |
| 3 | 180F + ID585 | 5.20 ± 4.20[b] | 0.085 ± 0.112[b] | 58.9 | 78.3 | 141.6 | 0.88 ± 0.77[b] | 0.017 ± 0.014[b] | 66.6 | 77.6 | 122.1 |
| 4 | 180F + ID585 | 5.41 ± 5.47[b] | 0.075 ± 0.082[b] | 56.6 | 70.1 | 147.2 | 1.05 ± 1.03[b] | 0.017 ± 0.016[b] | 62.5 | 72.1 | 112.7 |
| 5 | 1.8D + 6N | 3.81 ± 3.44[b] | * | * | * | * | 5.24 ± 5.00[c] | * | * | * | * |
| 6 | 1.8D + 6N | 6.56 ± 5.85[c] | * | * | * | * | 11.11 ± 6.64[d] | * | * | * | * |
| 8 | 1.8D + ID585 | 4.61 ± 3.83[b] | 0.062 ± 0.056[b] | 57.9 | 70.9 | 146.5 | 0.77 ± 0.59[b] | 0.011 ± 0.008[c] | 61.8 | 67.4 | 155.8 |
| 9 | Atlox 3409F + water | 0.32 ± 0.27[d] | 0.002 ± 0.003[c] | 41.3 | 56.1 | 155.6 | 0.23 ± 0.15[e] | 0.002 ± 0.001[d] | 46.9 | 53.7 | 108.6 |

*Incomplete analysis by flying spot scanner.
[a-e]For each column only: means followed by unlike letters are significantly different at P = 0.05.

Table VII. Aminocarb residue on foliage, Bathurst, N.B. 1981

| Block | Treatment | Host spp. | Date Sprayed | Date sampled | Aminocarb Deposit (µg/g) x ± S.D. |
|---|---|---|---|---|---|
| 1 | Matacil 180F + water | Sw | 12-06-81 | 12-06-81 | N/D* |
| | | Sr | 12-06-81 | 12-06-81 | 0.20 ± 0.17 |
| | | Bf | 12-06-81 | 12-06-81 | 1.38 ± 1.62 |
| 3 | Matacil 180 + ID585 | Sw | 12-06-81 | 12-06-81 | 0.30 ± 0.22 |
| | | Sr | 12-06-81 | 12-06-81 | 1.60 ± 0.00 |
| | | Bf | 12-06-81 | 12-06-81 | 0.94 ± 1.28 |
| 6 | Matacil 1.8D + GN oil | Sw | 13-06-81 | 14-06-81 | N/D |
| | | Sr | 13-06-81 | 14-06-81 | 0.38 ± 0.35 |
| | | Bf | 13-06-81 | 14-06-81 | 0.68 ± 0.59 |
| 8 | Matacil 1.8D + ID585 | Sw | 16-06-81 | 16-06-81 | N/D* |
| | | Sr | 16-06-81 | 16-06-81 | N/D* |
| | | Bf | 16-06-81 | 16-06-81 | 0.20 ± 0.12 |
| Check | Not sprayed | Sw | not sprayed | 01-06-81 | N/D* |
| | | Bf | not sprayed | 01-01-81 | N/D* |

* nondetectable levels.
Sw White spruce.
Sr Red spruce.
Bf Balsam fir.

XV. The prespray budworm populations in the blocks assessed both on the per branch and the per bud (shoot) bases were moderate with white spruce having the highest larval density and red spruce the lowest. The populations on balsam fir were fairly representative of the combined species. The initial populations were lowest generally in blocks 3 and 4 and highest in the untreated check area.

Larval densities for combined species recorded 10-12 days after the 2nd spray application averaged <1.0 insect/branch except in blocks 4 and 9 and the untreated check, and < 4/100 shoots in all blocks except 8, 9 and the check. These had residual larval densities exceeding 27 larvae/100 shoots (Table XI).

It became apparent when the tree species were assessed individually (Tables VIII-X) that low residual populations (per branch and per shoot) were left on balsam fir, except in block 9 and the check plot. Higher numbers of larvae appeared to survive on white spruce but this might have been due to the considerably higher prespray numbers found on this species. In a mixed coniferous stand red spruce characteristically seem to have much lower budworm populations. The data for the prespray populations in this study seem to support this (Table X); despite these low initial populations, the post spray residual densities on this species were still unacceptably high. It is likely that the sprays, though optimally timed for the other two host species, were

Table VIII. Larval spruce budworm population density on Balsam fir, *A. balsamea* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | Population Reduction | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Prespray | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 86 | 21.2+ | 8.3 | | 1.4 | | 1.0 | | 0.5 | |
| | | 18-06-81 | | 0.221++ | 0.093 | 2 | 0.023 | 2 | 0.022 | 6 | 0.009 | 10 |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 114 | 14.1 | 6.7 | | 1.3 | | 1.1 | | 0.6 | |
| | | 18-06-81 | | 0.133 | 0.083 | 2 | 0.021 | 2 | 0.018 | 6 | 0.011 | 10 |
| 3 | Matacil 180F + ID585 | 12-06-81 | 78 | 8.5 | 4.7 | | 0.8 | | 0.8 | | 0.4 | |
| | | 18-06-81 | | 0.084 | 0.059 | 3 | 0.011 | 2 | 0.015 | 7 | 0.007 | 11 |
| 4 | Matacil 180F + ID585 | 12-06-81 | 68 | 11.5 | 5.3 | | 1.2 | | 1.2 | | 1.2 | |
| | | 18-06-81 | | 0.095 | 0.046 | 3 | 0.014 | 3 | 0.017 | 7 | 0.025 | 11 |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 66 | 9.0 | 3.9 | | 1.0 | | 0.4 | | 0.3 | |
| | | 18-06-81 | | 0.077 | 0.043 | 5 | 0.015 | 4 | 0.004 | 8 | 0.006 | 12 |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 80 | 21.1 | 10.3 | | 0.7 | | 0.2 | | 0.2 | |
| | | 18-06-81 | | 0.192 | 0.115 | 4 | 0.007 | 4 | 0.002 | 8 | 0.004 | 12 |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 68 | 16.8 | 9.6 | | 2.5 | | 1.3 | | 0.3 | |
| | | 19-06-81 | | 0.185 | 0.115 | 2 | 0.032 | 4 | 0.028 | 8 | 0.007 | 12 |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 60 | 19.5 | 17.4 | | 20.2 | | 12.7 | | 10.9 | |
| | | 19-06-81 | | 0.173 | 0.193 | 3 | 0.255 | 4 | 0.285 | 8 | 0.357 | 12 |
| Check | Untreated | N/A | 60 | 26.8 | 18.0 | | 24.3 | | 16.0 | | 13.7 | |
| | | | | 0.232 | 0.258 | | 0.510 | | 0.446 | | 0.817 | |

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

* days after first spray sample taken.

** days after second spray sample taken.

Table IX. Larval spruce budworm population density on White spruce *P. glauca* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | Population Reduction | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pre-spray | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 10 | 54.5+ | 22.3 | | 4.3 | | 3.4 | | 1.1 | |
| | | 18-06-81 | | 0.394++ | 0.170 | 2 | 0.050 | 2 | 0.055 | 6 | 0.016 | 10 |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 0 | - | - | | - | | - | | - | |
| | | 18-06-81 | | - | - | | - | | - | - | - | |
| 3 | Matacil 180F + IDS85 | 12-06-81 | 28 | 25.4 | 13.7 | | 3.8 | | 2.5 | | 2.4 | |
| | | 18-06-81 | | 0.195 | 0.178 | 3 | 0.062 | 2 | 0.072 | 7 | 0.122 | 11 |
| 4 | Matacil 180F + IDS85 | 12-06-81 | 24 | 25.1 | 21.9 | | 8.9 | | 7.5 | | 2.6 | |
| | | 18-06-81 | | 0.195 | 0.217 | 3 | 0.338 | 3 | 0.515 | 7 | 0.051 | 11 |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 24 | 27.1 | 9.2 | | 1.8 | | 1.4 | | 1.4 | |
| | | 18-06-81 | | 0.221 | 0.096 | 5 | 0.057 | 4 | 0.023 | 8 | 0.016 | 12 |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 6 | 46.0 | 13.0 | | 1.8 | | 0.7 | | 0.2 | |
| | | 18-06-81 | | 0.198 | 0.092 | 4 | 0.042 | 4 | 0.006 | 8 | 0.005 | 12 |
| 8 | Matacil 1.8D OSC + IDS85 | 16-06-81 | 20 | 53.9 | 22.5 | | 8.9 | | 4.4 | | 2.5 | |
| | | 19-06-81 | | 0.432 | 0.213 | 2 | 0.105 | 4 | 0.544 | 8 | 1.305 | 12 |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 20 | 36.2 | 29.0 | | 19.7 | | 10.5 | | 7.6 | |
| | | 19-06-81 | | 0.339 | 0.454 | 3 | 1.332 | 4 | 2.510 | 8 | 0.286 | 12 |
| Check | Untreated | N/A | 30 | 66.3 | 23.5 | | 16.7 | | 7.6 | | 4.2 | |
| | | | | 0.365 | 0.297 | | 2.307 | | 1.502 | | 0.132 | |

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

* days after first spray sample taken.

** days after second spray sample taken.

Table X. Larval spruce budworm population density on Red spruce *P. rubens* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | Population Density | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Pre-spray | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 20 | 7.9+ | 4.4 | | 2.3 | | 2.0 | | 1.5 | |
| | | 18-06-81 | | 0.082++ | 0.040 | 2 | 0.028 | 2 | 0.022 | 6 | 0.015 | 10 |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 6 | 1.5 | 1.8 | | 1.2 | | 1.7 | | 0.8 | |
| | | 18-06-81 | | 0.028 | 0.014 | 2 | 0.015 | 2 | 0.021 | 6 | 0.007 | 10 |
| 3 | Matacil 180F + ID585 | 12-06-81 | 4 | 7.8 | 0.2 | | 0.2 | | 0.8 | | 0.2 | |
| | | 18-06-81 | | 0.047 | 0.006 | 3 | 0.005 | 2 | 0.016 | 7 | 0.003 | 11 |
| 4 | Matacil 180F + ID585 | 12-06-81 | 20 | 5.4 | 3.2 | | 2.4 | | 0.9 | | 1.6 | |
| | | 18-06-81 | | 0.042 | 0.028 | 3 | 0.025 | 3 | 0.011 | 7 | 0.013 | 11 |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 10 | 3.0 | 1.0 | | 0.1 | | 0.3 | | 0.2 | |
| | | 18-06-81 | | 0.032 | 0.009 | 5 | 0.002 | 4 | 0.002 | 8 | 0.003 | 12 |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 22 | 3.6 | 3.2 | | 2.5 | | 1.5 | | 0.6 | |
| | | 18-06-81 | | 0.022 | 0.014 | 4 | 0.014 | 4 | 0.016 | 8 | 0.006 | 12 |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 12 | 8.0 | 6.2 | | 5.0 | | 2.2 | | 1.6 | |
| | | 19-06-81 | | 0.053 | 0.062 | 2 | 0.051 | 4 | 0.036 | 8 | 0.032 | 12 |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 20 | 9.2 | 7.8 | | 13.1 | | 8.4 | | 7.9 | |
| | | 19-06-81 | | 0.061 | 0.066 | 3 | 0.153 | 4 | 0.097 | 8 | 0.101 | 12 |
| Check | Untreated | N/A | 30 | 9.2 | 14.9 | | 15.3 | | 12.3 | | 11.0 | |
| | | | | 0.082 | 0.126 | | 0.151 | | 0.172 | | 0.156 | |

Matacil treatments at 70 g AI/ha.

+ upper values denote insects per branch.

++ lower values denote insects per bud (shoot).

* days after first spray sample taken.

** days after second spray sample taken.

Table XI. Larval spruce budworm population density on combined species *A. balsamea, P. glauca* and *P. rubens* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | Population Density | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Prespray | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 116 | 21.8+ | 8.8 | | 1.8 | | 1.4 | | 0.7 | |
| | | 18-06-81 | | 0.221++ | 0.093 | 2 | 0.023 | 2 | 0.022 | 6 | 0.010 | 10 |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 120 | 13.5 | 6.5 | | 1.3 | | 1.2 | | 0.6 | |
| | | 18-06-81 | | 0.128 | 0.079 | 2 | 0.021 | 2 | 0.018 | 6 | 0.011 | 10 |
| 3 | Matacil 180F + ID585 | 12-06-81 | 110 | 12.8 | 6.8 | | 1.6 | | 1.2 | | 0.9 | |
| | | 18-06-81 | | 0.111 | 0.088 | 3 | 0.024 | 2 | 0.029 | 7 | 0.036 | 11 |
| 4 | Matacil 180F + ID585 | 12-06-81 | 112 | 13.3 | 8.5 | | 3.1 | | 2.5 | | 1.6 | |
| | | 18-06-81 | | 0.107 | 0.080 | 3 | 0.085 | 3 | 0.122 | 7 | 0.028 | 11 |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 100 | 12.7 | 4.9 | | 1.1 | | 0.6 | | 0.6 | |
| | | 08-06-81 | | 0.107 | 0.052 | 5 | 0.024 | 4 | 0.008 | 8 | 0.008 | 12 |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 108 | 19.0 | 9.0 | | 1.1 | | 0.5 | | 0.3 | |
| | | 18-06-81 | | 0.158 | 0.095 | 4 | 0.013 | 4 | 0.005 | 8 | 0.005 | 12 |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 100 | 23.2 | 11.8 | | 4.1 | | 2.0 | | 0.9 | |
| | | 19-06-81 | | 0.219 | 0.129 | 2 | 0.049 | 4 | 0.132 | 8 | 0.270 | 12 |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 100 | 20.8 | 17.8 | | 18.7 | | 11.4 | | 9.7 | |
| | | 19-06-81 | | 0.184 | 0.220 | 3 | 0.450 | 4 | 0.693 | 8 | 0.292 | 12 |
| Check | Untreated | N/A | 120 | 32.3 | 18.6 | | 20.2 | | 13.0 | | 10.6 | |
| | | | | 0.228 | 0.235 | | 0.870 | | 0.642 | | 0.480 | |

Matacil treatments at 70 g AI/ha.
+ upper values denote insects per branch.
++ lower values denote insects per bud (shoot).
* days after first spray sample taken.
** days after second spray sample taken.

Table XII. Larval spruce budworm population reduction and host tree defoliation on Balsam fir *A. balsamea* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | % Population Reduction (corrected) | | | | | | | | % Defoliation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** | |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 86 | 57.7+ | | 91.7 | | 93.4 | | 96.4 | | 10.4 |
| | | 18-06-81 | | 63.9 | 2 | 93.8 | 2 | 94.9 | 6 | 98.1 | 10 | |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 114 | 34.3 | | 85.1 | | 86.1 | | 91.5 | | 13.9 |
| | | 18-06-81 | | 57.0 | 2 | 90.2 | 2 | 92.0 | 6 | 95.3 | 10 | |
| 3 | Matacil 180F + ID585 | 12-06-81 | 78 | 20.3 | | 84.6 | | 82.6 | | 90.2 | | 10.4 |
| | | 18-06-81 | | 52.8 | 3 | 91.9 | 2 | 89.5 | 7 | 95.3 | 11 | |
| 4 | Matacil 180F + ID585 | 12-06-81 | 68 | 35.0 | | 83.0 | | 82.0 | | 79.0 | | 9.5 |
| | | 18-06-81 | | 67.4 | 3 | 90.8 | 3 | 89.4 | 7 | 84.9 | 11 | |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 66 | 36.1 | | 81.8 | | 92.0 | | 93.3 | | 6.1 |
| | | 08-06-81 | | 63.6 | 5 | 88.0 | 4 | 97.0 | 8 | 95.6 | 12 | |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 80 | 32.2 | | 94.8 | | 98.3 | | 98.9 | | 23.2 |
| | | 18-06-81 | | 59.6 | 4 | 97.7 | 4 | 99.4 | 8 | 98.9 | 12 | |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 68 | 25.6 | | 78.1 | | 86.6 | | 96.7 | | 20.7 |
| | | 19-06-81 | | 56.3 | 2 | 88.9 | 4 | 91.0 | 8 | 97.8 | 12 | |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 60 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 62.3 |
| | | 19-06-81 | | 21.5 | 3 | 5.6 | 4 | 0.0 | 8 | 0.0 | 12 | |
| Check | Untreated | N/A | 60 | N/A | | N/A | | N/A | | N/A | | 75.5 |

Matacil treatments at 70 g AI/ha.
+ upper values denote insects per branch.
++ lower values denote insects per bud (shoot).
* days after first spray sample taken.
** days after second spray sample taken.

Table XIII. Larval spruce budworm population reduction and host tree defoliation on White spruce *P. glauca* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | % Population Reduction (corrected) | | | | | | | | % Defoliation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** | |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 10 | 42.4+ | | 79.3 | | 75.4 | | 87.8 | | 30.9 |
| | | 18-06-81 | | 46.3++ | 2 | 79.3 | 2 | 74.4 | 6 | 86.4 | 10 | |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | - | - | | - | | - | | - | | - |
| | | 18-06-81 | 0 | - | | - | | - | | - | | |
| 3 | Matacil 180F + ID585 | 12-06-81 | 28 | 0.0 | | 37.7 | | 37.5 | | 17.2 | | 24.4 |
| | | 18-06-81 | | 0.0 | 3 | 0.0 | 2 | 0.0 | 7 | 0.0 | 11 | |
| 4 | Matacil 180F + ID585 | 12-06-81 | 24 | 0.0 | | 0.0 | | 0.0 | | 16.1 | | 31.0 |
| | | 18-06-81 | | 0.0 | 3 | 0.0 | 3 | 0.0 | 7 | 0.0 | 11 | |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 24 | 0.0 | | 70.0 | | 67.4 | | 54.8 | | 17.3 |
| | | 18-06-81 | | 0.0 | 5 | 36.7 | 4 | 15.8 | 8 | 0.0 | 12 | |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 6 | 23.5 | | 83.8 | | 91.3 | | 96.7 | | 27.8 |
| | | 18-06-81 | | 0.0 | 4 | 67.7 | 4 | 90.0 | 8 | 92.3 | 12 | |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 20 | 3.4 | | 42.2 | | 52.7 | | 68.4 | | 54.1 |
| | | 19-06-81 | | 0.0 | 2 | 14.5 | 4 | 11.6 | 8 | 47.1 | 12 | |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 20 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 73.4 |
| | | 19-06-81 | | 0.0 | 3 | 0.0 | 4 | 0.0 | 8 | 0.0 | 12 | |
| Check | Untreated | N/A | 30 | N/A | | N/A | | N/A | | N/A | | 76.3 |

Matacil treatments at 70 g AI/ha.
+ upper values denote insects per branch.
++ lower values denote insects per bud (shoot).
* days after first spray sample taken.
** days after second spray sample taken.

Table XIV. Larval spruce budworm population reduction and host tree defoliation on Red spruce *P. rubens* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | % Population Reduction (corrected) | | | | | | | | % Defoliation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** | |
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 20 | 40.0 | | 62.0 | | 64.0 | | 71.0 | | 3.8 |
| | | 18-06-81 | | 43.1 | 2 | 63.0 | 2 | 68.8 | 6 | 66.7 | 10 | |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 6 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 1.6 |
| | | 18-06-81 | | 0.0 | 2 | 0.0 | 2 | 0.0 | 6 | 0.0 | 10 | |
| 3 | Matacil 180F + ID585 | 12-06-81 | 4 | 96.0 | | 96.0 | | 81.0 | | 95.0 | | 0.1 |
| | | 18-06-81 | | 96.9 | 3 | 96.4 | 2 | 79.2 | 7 | 85.7 | 11 | |
| 4 | Matacil 180F + ID585 | 12-06-81 | 20 | 15.8 | | 29.4 | | 71.0 | | 42.9 | | 2.8 |
| | | 18-06-81 | | 20.0 | 3 | 0.0 | 3 | 72.7 | 7 | 47.4 | 11 | |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 10 | 58.0 | | 94.4 | | 82.4 | | 86.7 | | 1.5 |
| | | 18-06-81 | | 50.0 | 5 | 94.4 | 4 | 75.0 | 8 | 85.7 | 12 | |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 22 | 0.0 | | 0.0 | | 28.6 | | 66.7 | | 4.8 |
| | | 18-06-81 | | 0.0 | 4 | 0.0 | 4 | 8.3 | 8 | 70.0 | 12 | |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 12 | 0.0 | | 7.4 | | 52.2 | | 63.6 | | 9.2 |
| | | 19-06-81 | | 0.0 | 2 | 2.9 | 4 | 46.4 | 8 | 57.7 | 12 | |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 20 | 0.0 | | 0.0 | | 0.0 | | 0.0 | | 19.7 |
| | | 19-06-81 | | 0.0 | 3 | 0.0 | 4 | 0.0 | 8 | 0.0 | 12 | |
| Check | Untreated | N/A | 30 | N/A | | N/A | | N/A | | N/A | | 26.5 |

Matacil treatments at 70 g AI/ha.
+ upper values denote insects per branch.
++ lower values denote insects per bud (shoot).
* days after first spray sample taken.
** days after second spray sample taken.

Table XV. Larval spruce budworm population reduction and host tree defoliation on combined species *A. Balsamea, P. glauca* and *P. rubens* (Bathurst, N.B. 1981)

| Block | Spray Formulations | Spray Dates | No. of Samples | % Population Reduction (corrected) 1st count | * | 2nd count | ** | 3rd count | ** | 4th count | ** | % Defoliation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 116 | 55.3+ | | 88.3 | | 90.1 | | 94.4 | | 14.5 |
| | | 18-06-81 | | 50.3++ | 2 | 82.8 | 2 | 79.6 | 6 | 88.4 | 10 | |
| 2 | Matacil 180F + Atlox + $H_2O$ | 12-06-81 | 120 | 30.9 | | 83.1 | | 82.4 | | 89.8 | | 13.3 |
| | | 18-06-81 | | 0.0 | 2 | 58.0 | 2 | 55.0 | 6 | 65.6 | 10 | |
| 3 | Matacil 180F + ID585 | 12-06-81 | 110 | 20.9 | | 78.1 | | 80.6 | | 83.3 | | 13.5 |
| | | 18-06-81 | | 0.0 | 3 | 44.2 | 2 | 12.1 | 7 | 0.0 | 11 | |
| 4 | Matacil 180F + ID585 | 12-06-81 | 112 | 1.1 | | 59.2 | | 62.1 | | 72.4 | | 12.9 |
| | | 18-06-81 | | 0.0 | 3 | 0.0 | 3 | 0.0 | 7 | 0.0 | 11 | |
| 5 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 100 | 38.8 | | 84.3 | | 90.2 | | 88.9 | | 8.7 |
| | | 18-06-81 | | 0.0 | 5 | 40.0 | 4 | 75.0 | 8 | 68.0 | 12 | |
| 6 | Matacil 1.8D OSC + Sunspray 6N | 13-06-81 | 108 | 29.1 | | 89.8 | | 94.7 | | 96.4 | | 19.9 |
| | | 18-06-81 | | 0.0 | 4 | 79.0 | 4 | 89.8 | 8 | 87.5 | 12 | |
| 8 | Matacil 1.8D OSC + ID585 | 16-06-81 | 100 | 29.3 | | 70.9 | | 82.8 | | 91.7 | | 26.0 |
| | | 19-06-81 | | 0.0 | 2 | 48.4 | 4 | 0.0 | 8 | 0.0 | 12 | |
| 9 | Atlox 3409F + $H_2O$ | 15-06-81 | 100 | 0.0 | | 0.0 | | 0.0 | | 1.0 | | 56.0 |
| | | 19-06-81 | | 0.0 | 3 | 0.0 | 4 | 0.0 | 8 | 0.0 | 12 | |
| Check | Untreated | N/A | 120 | 19.8 | | 0.0 | | 27.4 | | 32.5 | | 63.5 |
| | | | | 0.0 | | 0.0 | | 0.0 | | 0.0 | | |

Matacil treatments at 70 g AI/ha.
+ upper values denote insects per branch.
++ lower values denote insects per bud (shoot).
* days after first spray sample taken.
** days after second spray sample taken.

not as effective on red spruce because its phenological development was retarded and consequently its budworm population was not optimally accessible and susceptible to the sprays. Since red spruce was a minor component of all the sprayed areas (Table I) its late development might not have significantly influenced the spray's overall effects.

Aqueous Matacil 180F generally controlled spruce budworm as effectively as either the 180F in ID585 or the oil soluble concentrate in oil. The block sprayed with Atlox + water had residual larval densities not substantially different from the untreated check, thereby indicating that Atlox was not noticeably toxic to spruce budworm.

The two methods of population assessment did not appear to show any significant difference in trends. However, there were occasions where the insect to shoot ratio appeared to increase rather than decline (Table VIII). This was due to defoliation by the insects which reduced the number of viable shoots thus making the denominator in the 'insect:shoot' equation progressively smaller. This type of 'per shoot' assessment is in reality a combination of assessing, simultaneously, both the insect numbers and some of the tree defoliation. We have subsequently found that this anomaly can be avoided by adjusting the counting mill technique to include in the denominator all shoots on the branch and not only the viable ones. The variance observed in the number of shoots per branch should therefore be that found in heterogenous forest systems and not induced by insect feeding which is independently measured as the degree of defoliation.

*Percent Population Mortality*

The percent insect mortality attributed to the treatments is considered as one of the most important and definitive expressions of the treatment's effectiveness. In this study all the treatments except Atlox + water gave very good percent larval mortality. Generally, the results showed no appreciable differences between the two assessment methods except on white spruce which reflected those anomolies in larval population densities discussed earlier. It was also observed that untreated populations in white spruce (Table IX) showed a high natural mortality which might have been due to the high numbers competing for limited food. Consequently, this resulted in the low corrected mortality figures shown for that species (Table XIII). Using percent larval mortality as an assessment criterion the results again indicate that Matacil flowable was as effective in reducing spruce budworm populations as the OSC. There was no observable toxicity to budworm which could be attributed to Atlox + water.

*Arthropod Knockdown*

The observations in this study were focused mainly on *C. fumiferana* and the results show that considerably more live than dead budworm were dislodged and that the bulk fell 2-3 days after the spray application (Fig. 6). Larval spruce budworm tend to react to unfamiliar stimuli by spinning out of their immediate habitat on silken threads which cascade in large quantities from the canopy like tinsel on a Christmas tree. This tinselling was evident in all the sprayed blocks. It was spectacular in blocks 1 and 2 (aqueous Matacil) one to

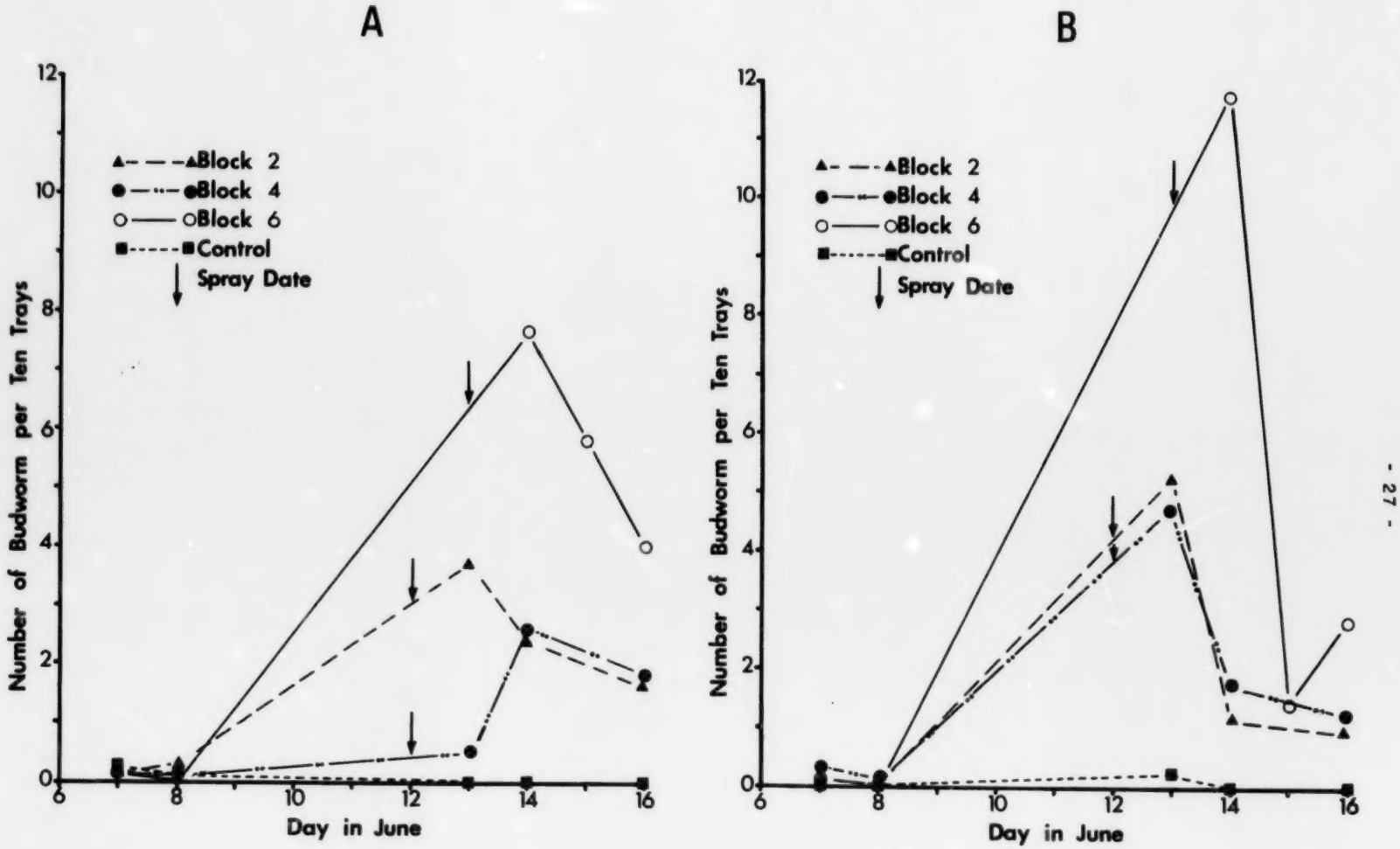


Fig. 6. Number of dead (A) and line (B) budworm collected prior to and after Matacil spray. Bathurst, N.B. 1981.

three days after the first spray application and barely observable in the block sprayed with Atlox + water. Matacil OSC + Sunspray 6N showed the greatest knockdown of larval budworm but the tinselling in the block was not unusually striking. These findings imply that substantial larval dislodgement could occur without its being manifested by tinselling and that stimuli other than regular droplets, possibly vapors or aerosols, might have caused the excessive larval irritability seen in the aqueous Matacil blocks. It was evident that, depending on the conformation of the host tree canopy, tinselling might result in intra-tree redistribution of budworm and not necessarily in ultimate dislodgement. However, unless the lower canopy is supportive, this redistribution might be just as catastrophic for larvae as dislodgement.

The Environmental Impact section of FPMI conducted a more thorough study of the impact of the treatments on terrestrial invertebrates and the report indicates that Coleoptera: Staphilinidae and Diptera were the only insects knocked down in sufficient numbers to merit any concern (R.L. Millikin --FPMI File Rept. No. 15). Even so, the techniques used during that study would suggest that the receptacles containing a formalin solution which were placed beneath the trees possibly did not just passively collect dislodged insects, but behaved as lures and also actively trapped some of them.

During our assessment of budworm knockdown it was observed that spiders appeared to be affected by Matacil. This is not unusual as some carbamates tend to display acaricidal characteristics. The results from our collection on drop trays show that Matacil was toxic to 8 genera of spiders (Table XVI), *Theridion montanum* Emerton was the species which appeared to be most affected. Whereas a high proportion of the dislodged larval insects were alive, all of the spiders were dead.

*Defoliation*

The extent of host tree defoliation is a function of the feeding activity of insect pests. This activity is in turn influenced mainly by the size and health of the insect population, the tree vigor, and the weather. Insecticides are applied to affect the first two factors. The results (Tables XII to XIV) indicate that white spruce was most heavily defoliated and red spruce the least. However, these species also recorded the highest and lowest initial budworm populations respectively. The blocks sprayed with Matacil flowable in both water and ID585 suffered >15% defoliation except on white spruce. This is substantially better foliage protection than was received by blocks sprayed with the OSC, which experienced >5% defoliation except on balsam fir in block 5 and on red spruce. On a combined species basis, Matacil 180F was also as effective in protecting foliage from budworm defoliation as the other Matacil treatments (Table XV). All three species in the Atlox block were defoliated to a similar extent as in the untreated block (Table XV).

*Spray Deposit-Spruce Budworm Relationships*

Aerially applied droplets in forests have seldom shown a consistent pattern of behavior. This is not surprising if one considers the extreme heterogeneity in natural forests and the diverse factors which can influence the sprays. The optimum and desirable droplet sizes to control various insects have been widely discussed (Himel and Moore 1967; Barry *et al.* 1977; Joyce and Spillman 1978) and there is agreement that it is also necessary to have good coverage in terms of droplet density. Even so, aerial spray deposits and insect mortality often will not give correlation when cards are used to collect droplets (Buffman *et al.* 1967). Although the average droplet densities recorded in this study were not high (Table VI), it was shown that budworm population reduction was generally related

Table XVI. Spiders knocked down on three Matacil blocks (Bathurst, N.B. 1981)

| Block No. and Treatment | Species | Number of Spiders Dislodged | |
|---|---|---|---|
| | | at Prespray | at Postspray |
| 2 | *Clubiona* sp. | 0 | 6 |
| 180F + water + Atlox | *Dictyra phylax* Gérisch & Ivie | 0 | 1 |
| | *Theridion montanum* Emerton | 0 | 6 |
| 4 | *Araneus* sp. | 1 | 0 |
| 180F + ID585 | *Ceraticelus fissiceps* (O.P.-Cambridge) | 0 | 2 |
| | *Clubiona* sp. | 0 | 3 |
| | *Grammonata angusta* Dondale | 0 | 1 |
| | *Metaphidippus* sp. | 0 | 2 |
| | *Theridion montanum* | 0 | 2 |
| 9 | *Araneus* sp. | 0 | 2 |
| | *Clubiona* sp | 0 | 2 |
| 1.8D + 6N | *Grammonata angusta* | 1 | 1 |
| | *Metaphidippus* sp. | 0 | 2 |
| | *Philodromus cespitum* (Walckenaer) | 0 | 1 |
| | *Theridion montanum* | 0 | 16 |
| unsprayed check | *Theridion montanum* | 1 | 0 |

to droplet density (Tables XVII to XIX). This relationship was more definitive in balsam fir than in the other host species, but this might be due to a statistically more acceptable number of samples in fir. We also found that the per shoot assessment of percent population reduction seemed to give inflated relationships, probably because of the denominator anomaly mentioned earlier. In all the treatments except aqueous Matacil on red spruce, 1 drop/$cm^2$ on Kromekote cards gave the least control and the classes 1-5, 5-10 drops/$cm^2$ the most consistently favourable results (Tables XVI to XIX).

## CONCLUSIONS

Matacil 180F was as effective in controlling *C. fumiferana* on *A. balsamea* and *Picea* spp. as the oil soluble concentrate formulation. Both the flowable in ID585 and in water and the OSC in ID585 and Sunspray 6N effected ∿90% corrected larval reduction, residual larval populations generally <1.0/46 cm branch tip, and very good foliage protection.

The 180F mixed easily and presented no application problems. The deposition characteristics between that and the OSC were not substantially different.

The formulation showed no pronounced adverse effect on nontarget insect species; however a small number of spiders were collected on drop trays.

It was shown that aqueous tank formulations, once thought to be liabilities because of their propensity to evaporate and result in inadequate deposit, can be most efficaceous, when applied with aircraft with delivery systems and under conditions which

Table XVI I. Droplet density and spruce budworm mortality on Balsam fir *A. balsamea* (Bathurst, N.B. 1981)

| Block No. | Treatment | Deposit Class. (Drops/cm$^2$) | Number of samples | % Pop. reduction* | |
|---|---|---|---|---|---|
| | | | | Per branch | Per bud |
| 1 | Matacil + Atlox + water | 0-1 | 21 | 47 | 58 |
| | | 1-5 | 17 | 66 | 73 |
| | | 5-10 | 4 | 85 | 89 |
| 2 | Matacil 180F + Atlox + water | 0-1 | 25 | 16 | 66 |
| | | 1-5 | 27 | 44 | 74 |
| | | 5-10 | 3 | 61 | 87 |
| | | 10-15 | 1 | 81 | 92 |
| 3 | Matacil 180F + ID585 | 0-1 | 3 | 0 | 52 |
| | | 1-5 | 17 | 0 | 58 |
| | | 5-10 | 12 | 60 | 88 |
| | | 10-15 | 4 | 85 | 92 |
| | | 15-20 | 0 | - | - |
| | | 20-25 | 1 | 18 | 76 |
| 4 | Matacil 180F + ID585 | 0-1 | 6 | 0 | 54 |
| | | 1-5 | 12 | 35 | 80 |
| | | 5-10 | 6 | 76 | 91 |
| | | 10-15 | 7 | 48 | 83 |
| | | 15-20 | 3 | 79 | 92 |
| 8 | Matacil OSC + ID585 | 0-1 | 2 | 0 | 46 |
| | | 1-5 | 21 | 20 | 67 |
| | | 5-10 | 6 | 52 | 85 |
| | | 10-15 | 2 | 68 | 77 |
| | | 15-20 | 2 | 4 | 63 |
| 9 | Atlox 3409F + water | 0-1 | 26 | 0 | 50 |
| | | 1-5 | 1 | 0 | 49 |

Droplets from blocks 5 and 6 not included due to incomplete analysis by the spot scanner.
* Assessed 2 days after 1st application.

capitalize on the evaporative potential to produce optimum sized droplets at the target sites.

Assessments of larval budworm populations using per bud and per branch methods generally produced similar results.

The initial phenological development of red spruce *P. rubens* was much slower than that of either *P. glauca* or *A. balsamea*. Pesticide applications timed to the development of the latter two possibly were not as effective on the former. Thus the species composition of a forest should be of prime

Table XVIII. Droplet density and spruce budworm mortality on White spruce *P. glauca* (Bathurst, N.B. 1981)

| Block No. | Treatment | Deposit Class. (Drops/cm$^2$) | Number of samples | Pop. reduction* % | |
|---|---|---|---|---|---|
| | | | | Per branch | Per bud |
| 1 | Matacil 180F + Atlox + water | 0-1 | 3 | 43 | 48 |
| | | 1-5 | 2 | 58 | 72 |
| 2 | Matacil 180F + Atlox + water | - | - | - | - |
| 3 | Matacil + ID585 | 0-1 | 3 | 0 | 0 |
| | | 1-5 | 6 | 0 | 61 |
| | | 5-10 | 5 | 26 | 76 |
| 4 | Matacil ID585 | 0-1 | 3 | 0 | 39 |
| | | 1-5 | 8 | 0 | 48 |
| 8 | Matacil 1.8D + ID585 | 0-1 | 1 | 0 | 75 |
| | | 1-5 | 5 | 27 | 60 |
| | | 5-10 | 4 | 0 | 74 |
| 9 | Atlox 3409F + water | 0-1 | 10 | 0 | 10 |

Droplets from block 5 & 6 included due to incomplete analysis by the spot scanner.
* Assessed 2 days after 1st application.

consideration in determining the timing of applications to control defoliators.

The response of *C. fumiferana* to Atlox 3409F sprayed as an independent treatment were similar to those seen in the unsprayed check block. It is therefore apparent that whereas Atlox might improve the sprayability and consequently the efficacy of aqueous Matacil there is no evidence that it contributes insecticidally to the formulation.

Table XIX. Droplet density and spruce budworm mortality on Red spruce *P. rubens* (Bathurst, N.B. 1981)

| Block No. | Treatment | Deposit Class. (Drops/cm$^2$) | Number of samples | Pop. reduction* | |
|---|---|---|---|---|---|
| | | | | Per branch | Per bud |
| 1 | Matacil + Atlox + water | 0-1 | 4 | 48 | 57 |
| | | 1-5 | 5 | 33 | 55 |
| | | 5-10 | 1 | 28 | 17 |
| 2 | Matacil + Atlox + water | 0-1 | 3 | 0 | 63 |
| 3 | Matacil 180F + ID585 | 0-1 | 0 | - | - |
| | | 1-5 | 0 | - | - |
| | | 5-10 | 2 | 95 | 91 |
| 4 | Matacil 180F + ID585 | 0-1 | 0 | - | - |
| | | 1-5 | 4 | 0 | 32 |
| | | 5-10 | 5 | 30 | 62 |
| | | 10-15 | 0 | - | - |
| | | 15-20 | 0 | - | - |
| | | 20-25 | 1 | 0 | 0 |
| 8 | Matacil 1.8D + ID585 | 0-1 | 0 | - | - |
| | | 1-5 | 4 | 26 | 38 |
| | | 5-10 | 2 | 0 | 0 |
| 9 | Atlox 3409F + water | 0-1 | 5 | 0 | 0 |
| | | 1-5 | 1 | 0 | 0 |

Droplets from blocks 5 and 6 not included due to incomplete analysis by the spot scanner.

* Assessed 2 days after 1st application.

REFERENCES

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18(2):265-267.

Barry, J.W.; Ciesla, W.K.; Tysowski; Ekblad, R.B. 1977. Impaction of insecticide particles on western spruce budworm and Douglas fir needles. J. Econ. Entomol. 70(3):387-388.

Blais, J.R. 1957. Some relationships of the spruce budworm *Choristoneura fumiferana* (Clem.) to black spruce, *Picea mariana* (Moench) Voss. Forest Chronicle 33(4):364-372.

Buffman, P.E.; Meyer, H.E.; Miskus, R.P. 1967. Small-scale trials of five insecticides sprayed on spruce budworm in Montana. U.S. For. Serv. Res. Notes PSW 159. 4 pp.

Drummond, A.M. 1980. The effect of droplet density and sample area on variability of results by the flying spot scanner. Can. Nat. Res. Council Lab. Tech. Rep. LTR-FR-76. 38 pp.

Fettes, J.J. 1950. Investigations of sampling techniques for population studies of the spruce budworm or balsam fir in Ontario. For. Ins. Lab., Sault Ste. Marie, Ann. Tech. Rep. 4:163-401.

Himel, C.M.; Moore, A.D. 1967. Spruce budworm mortality as a function of aerial spray droplet size. Science 156(3779): 1250-1251.

Joyce, R.J.; Spillman, J.J. 1978. Discussion of aerial spraying techniques. pp. 13-44 *in* A.V. Holden and D. Bevan, eds., Control of Pine beauty moth by Fenitrothion. Forestry Commission Survey, U.K.

Martineau, R.; Benoit, P. 1973. A sampling technique for estimating numerical trends on larval populations of insect defoliators on conifers. II. Modification and operational use of the technique for extensive sampling. Phytoprotection 54(1):23-32.

Randall, A.P. 1967. Summary report on insecticide investigation. Report of the 1967 Pest Control Forum. Can. For. Serv., Ottawa.

Randall, A.P. 1980. A simple device for collecting aerial spray deposits from calibration trials and spray operations. Can. For. Serv., Bi-mon. Res. Notes 36(5):23.

Sundaram, K.M.S.; Volpe, Y.; Smith, G.C.; Duffy, J.R. 1976. A preliminary study on the persistence and distribution of Matacil in a forest environment. Can. For. Serv., Environ. Can., Rep. CC-X-116.